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PARSONS ENGINEERING SCIENCE, INC.

1700 Broadway, Suite 900 • Denver, Colorado 80290 • (303) 831-8100 • Fax: (303) 831-8208

February 28, 1997

Captain Ed Marchand
AFCEE/ERT
3207 North Road, Bldg. 532
Brooks AFB, Texas 78235-5363

Subject: Results of Bioventing System Monitoring at Sites ST12-A and ST12-B, Waikakalaua Fuel Storage Annex (FSA), Hickam Petroleum, Oils, and Lubricants (POL) System, Hawaii (Contract F41624-92-8036, Order 17)

Dear Captain Marchand:

This letter presents the results of the bioventing system monitoring performed by Parsons Engineering Science, Inc. (Parsons ES) in December 1996 at Sites ST12-A and ST12-B, located at the Waikakalaua Fuel Storage Annex (FSA) administered by Hickam Air Force Base (AFB), Hawaii. Soil gas samples were collected and *in situ* respiration testing was performed by Parsons ES between 10 and 23 December 1996 to assess the extent of remediation completed during approximately 3.5 years of air injection bioventing at Site ST12-A and 1 year of air injection bioventing at Site ST12-B. The purpose of this letter is to summarize remediation activities to date, present the results of the December 1996 system monitoring event and compare them with the results of previous monitoring events, and to outline future remediation activities planned for Sites ST12-A, ST12-B, and ST10, which is located at Valve Pit 17 on the Hickam POL pipeline near Kipapa FSA.

SITE REMEDIATION HISTORY

Sites ST12-A and ST12-B are specific areas located at the Waikakalaua FSA, which in its entirety is designated as Site ST12 (Figure 1, attached). The Waikakalaua FSA is a former bulk fuel storage and handling facility located approximately 9 miles north-northwest of Hickam AFB on the island of Oahu. Nine cylindrical underground fuel storage tanks, each with a capacity of 1.75 million gallons, were constructed at the annex and used to store aviation gasoline and JP-4 jet fuel. The Waikakalaua FSA operated as the northern terminus of the Hickam POL system, which was used to supply fuel to Pearl Harbor and Hickam AFB from 1943 until 1993. In April 1993, the Hickam POL system, including the Waikakalaua FSA, was abandoned.

Sites ST12-A and ST12-B are the locations of open-bottomed disposal basins that previously were used for disposal of petroleum-contaminated condensate from the FSA. Condensate was released into the open-bottomed disposal basins and allowed to infiltrate into the subsurface. Figures 2 and 3 (attached) present layouts of Sites ST12-A and ST12-B, respectively, and illustrate the locations of the open-bottomed disposal basins, monitoring wells (MWs), vent wells (VWs), soil vapor monitoring points

(MPs), regenerative blower systems, and other remediation system components installed at the sites.

The initial subsurface investigation at these sites was performed in 1988 by Harding Lawson Associates (HLA, 1992), and included the construction of MW-6 at Site ST12-A and MW-7 at Site ST12-B. At MW-6, the geologic profile consists of clayey silt to 20 feet below ground surface (bgs), saprolite (weathered basalt) from 20 to 110 feet bgs, and basalt from 110 feet bgs to the total depth of the borehole at 155 feet bgs. Petroleum-contaminated soils and saprolite were encountered in the MW-6 borehole at depths ranging from 30 feet to at least 90 feet bgs, based on field headspace screening results. Total recoverable petroleum hydrocarbon (TRPH) concentrations in soil samples from the MW-6 borehole measured as high as 3,980 milligrams per kilogram (mg/kg). At MW-7, the geologic profile consists of clayey silt to 60 feet bgs, saprolite from 60 to 105 feet bgs, and basalt from 105 feet bgs to the total borehole depth of 155 feet bgs. Contaminated soils and saprolite were encountered in the MW-7 borehole at depths ranging from 55 to at least 90 feet bgs. TRPH concentrations in soil samples from the MW-7 borehole measured as high as 594 mg/kg.

Although groundwater was not encountered in this drilling effort, monitoring wells were constructed using 4-inch diameter polyvinyl chloride (PVC) casing and screen in each borehole. MW-6 was constructed to a total depth of 150 feet bgs, and was screened in the basalt from 135 to 150 feet bgs with 20-slot screen. MW-7 was constructed to a total depth of 155 feet bgs, and was screened in the basalt from 135 feet to 155 feet bgs with 20-slot screen.

In 1993, Engineering-Science, Inc. (ES, now known as Parsons ES) installed three deep groundwater monitoring wells (ST12MW03, ST12MW04, and ST12MW05) into the basal groundwater aquifer, which occurs at depths ranging from approximately 650 to 730 feet bgs at the Waikakalaua FSA. At Site ST12-B, elevated photoionization detector (PID) readings were observed in the coring for ST12MW03 at depths ranging from 60 to 130 feet bgs, confirming the presence of petroleum contamination in saprolite and shallow basalt. Low levels of dissolved petroleum hydrocarbon constituents have been detected in groundwater samples collected from ST12MW03. No petroleum hydrocarbon contamination was encountered in soil, rock, or groundwater at ST12MW04 or ST12MW05.

In March and April 1993, a pilot-scale bioventing system was installed at Site ST12-A by ES as part of the Air Force Center for Environmental Excellence (AFCEE) Bioventing Pilot Test Initiative (Contract No. F33615-90-D-4014, Order 14). The installed pilot-scale bioventing system consisted of one VW (VW-1), four soil vapor MPs (MPA, MPB, MPC, and a background MP designated as MPBG), and a regenerative blower unit configured for air injection into VW-1. During the installation of the pilot-scale system, soil and soil gas sampling and respiration and air permeability testing were performed. Petroleum-contaminated soil and/or soil gas was encountered at all locations except MPBG. A more detailed description of the pilot-scale bioventing system design and installation and pilot testing results are provided in

the August 1993 Interim Bioventing Pilot Test Results report prepared for this site (ES, 1993).

The Bioventing Pilot Test Initiative provided for 1 year of pilot-scale system operation followed by soil and soil gas sampling and *in situ* respiration testing at Site ST12-A. Soil and soil gas samples were collected and *in situ* respiration testing was performed in May 1994 following 1 year of system operation. The system was shut down approximately 30 days prior to testing to allow soils and soil gas to come to equilibrium in order to compare 1-year and initial conditions. Results from the 1-year bioventing pilot test were reported by AFCEE (1995) and demonstrated that *in situ* bioventing could be an effective method to remediate vadose zone soils at Site ST12-A by aerobically enhancing biological fuel degradation.

Based on the favorable bioventing pilot testing results at Site ST12-A and other Hickam POL locations, bioventing scopes of work at Site ST12-A, Site ST12-B, and Site ST10 (at Valve Pit 17 on the Hickam POL pipeline near Kipapa FSA) were added to the AFCEE Extended Bioventing Project (Contract No. F41624-92-D-8036, Order 17) on 31 March 1995. Under the Extended Bioventing Project, Site ST12-A was allocated funding for bioventing system expansion (Option 4); and for 1 year of system maintenance with year-end respiration testing and soil gas sampling (Option 1). Sites ST10 and ST12-B each were allocated funding for pilot-scale system installation and testing (Option 3) and for 1 year of system maintenance with year-end testing (Option 1). This letter reports the Option 1 year-end testing events for Sites ST12-A and ST12-B.

In September 1995, Parsons ES (1995) finalized a Bioventing Pilot Test and Expanded Treatability Study Work Plan, which detailed proposed pilot testing and system installation at Sites ST12-A, ST12-B, and ST10. The bioventing system expansion at Site ST12-A and the pilot-scale system installation and testing at Sites ST12-B and ST10 were performed according to the work plan in October and November 1995. At Site ST12-A, an additional vent well (VW-2) and soil vapor MP (MPD) were installed. Petroleum-contaminated soil and/or soil gas were encountered in each borehole. An upgraded regenerative blower system was installed and plumbed for air injection into VW-1, VW-2, and the existing monitoring well MW-6 (see attached Figure 2). At Site ST12-B, one VW (VW-1), three soil vapor MPs (MPA, MPB, and MPC), and a regenerative blower system were installed. Petroleum hydrocarbon contamination was encountered in each borehole location. The pilot-scale bioventing system at Site ST12-B was plumbed for air injection into VW-1 and existing monitoring well MW-7 (see attached Figure 3). Although a pilot-scale bioventing system also was installed at Site ST10, the system could not be started and operated due to problems with the electrical system at the site. Initial results of the expanded treatability testing at Site ST12-A and the bioventing pilot testing at Sites ST12-B and ST10 were provided in the May 1996 Bioventing Pilot Test and Expanded Treatability Study Results Report (Parsons ES, 1996).

Operation of the bioventing systems under the Option 1s at Site ST12-A and ST12-B began on 13 November 1995 and continued until a power outage shut down both

systems at some time between August and October 1996. Both systems remained shut down until power was restored in January 1997. The blower system at Site ST12-A also was shut down for a period of time in Spring 1996 to allow for repairs to the electrical system, which was performed by Parsons ES using Option 1 funding. The electrical power outage at Sites ST12-A and ST12-B occurred approximately 2 to 4 months prior to Option 1 testing, allowing equilibrium conditions to develop in site soils, thereby allowing for comparison to previous soil gas sampling and respiration testing results.

OPTION 1 TESTING RESULTS

Site ST12-A - Soil Gas Chemistry Results

Soil gas samples were collected for field screening and laboratory analysis at Site ST12-A in December 1996. Soil gas sampling results from this Option 1 testing event, as well as soil gas sampling results from previous system installation and monitoring events, are presented in Table 1 (attached). In the December 1996 sampling event, static soil gas oxygen concentrations were below 5 percent at all sampling locations except VW-2, MW-6, and MPD-31, indicating that significant oxygen demand still exists in the soils, and that aerobic fuel biodegradation is still taking place at significant rates. High oxygen levels at VW-2 and MW-6 are the result of long-term air injection at these points; most of the fuel contamination initially present at these locations has been aerobically biodegraded or has volatilized and moved away from the injection point via soil gas advection. Soils at MPD-31 are not contaminated with petroleum hydrocarbons, and the high oxygen concentration at this point reflects the lack of substrate (e.g., fuel hydrocarbons) in soils. Generally, static soil gas oxygen concentrations at Site ST12-A have decreased, and static carbon dioxide concentrations have increased in comparison to prior sampling events, possibly indicating increased aerobic biological activity in fuel-contaminated soils. Field soil gas total volatile hydrocarbon (TVH) concentrations at or exceeding 10,000 parts per million, volume per volume (ppmv) were detected at five sampling locations, indicating that significant levels of volatile petroleum hydrocarbons still exist in site soils.

No power for 4 months

Soil gas samples collected at MW-6, MPA-70, MPB-36.1, MPC-37.6, and MPD-101.5, were submitted under chain-of-custody to the Air Toxics, Ltd. laboratory in Folsom, California, and analyzed for TVH, benzene, toluene, ethylbenzene, and total xylenes (BTEX) using US Environmental Protection Agency (USEPA) Method TO-3. At all locations except MW-6, which had been used for air injection, TVH levels in soil gas were extremely high, ranging from 40,500 to 110,000 ppmv. Although TVH levels remained high, significant decreases in soil gas BTEX concentrations were noted. These data indicate that although TVH levels at Site ST12-A are very high, the risk-driving BTEX compounds are being preferentially destroyed by bioventing system operation.

Site ST12-A - Respiration Testing Results

After the soil gas sampling was completed at Site ST12-A, an *in situ* respiration test was performed according to procedures outlined in the AFCEE bioventing protocol document (Hinchee *et al.*, 1992). Air was injected for 22 hours into MW-6, MPA-24.3, MPB-36.1, and for 18.5 hours into MPD-101.5 using 1-cubic-foot-per-minute (cfm) pumps to locally oxygenate the soils. Following the air injection period, changes in soil gas oxygen, carbon dioxide, and TVH concentrations were monitored over a 72 hour period. Observed rates of oxygen utilization were then used to estimate aerobic fuel biodegradation rates. Table 2 (attached) presents the results of respiration testing performed at Site ST12-A in December 1996 and during previous events.

Oxygen utilization rates were still significant at all testing locations except MW-6, which had been used for air injection. Oxygen utilization rates at testing points excluding MW-6 ranged from 0.33 to 0.47 percent per hour, with estimated fuel biodegradation rates ranging from 440 to 1,400 mg/kg per yr. Fuel consumption rates in December 1996 were generally the same as they had been in previous testing events, indicating that a significant amount of fuel hydrocarbons remain in soils, and that fuel biodegradation will continue to be enhanced by air injection bioventing.

Site ST12-B - Soil Gas Chemistry Results

Soil gas samples were collected for field-screening and laboratory analysis at Site ST12-B in December 1996, following at least 3 months of system shutdown. Soil gas sampling results from this Option 1 testing event, as well as soil gas sampling results from the initial pilot testing event, are presented in Table 3 (attached). In the December 1996 sampling event, static soil gas oxygen concentrations were above 5 percent at all sampling locations except MPB-71 and MPB-91, indicating that oxygen demand in the soils has decreased significantly since pilot-scale system installation, and that aerobic fuel biodegradation is only occurring at significant rates in the silt and saprolite layers at depths ranging from approximately 60 to 100 feet bgs at MPB. Field soil gas TVH concentrations at or exceeding 10,000 ppmv were detected at five sampling locations, indicating that significant levels of volatile petroleum hydrocarbons still exist in site soils.

Soil gas samples collected at VW-1, MPA-65, MPB-71, MPB-91, MPC-65, and MPC-90 were submitted under chain-of-custody to the Air Toxics, Ltd. laboratory in Folsom, California, and analyzed for TVH and BTEX using USEPA Method TO-3. At all locations except VW-1, which had been used for air injection, TVH levels in soil gas were extremely high, ranging from 16,000 to 200,000 ppmv. TVH concentrations increased slightly at all MP locations except for MPC-65. However, BTEX concentrations decreased substantially at all points resampled. This indicates that although TVH levels are still high, the risk-driving BTEX compounds are being preferentially destroyed by bioventing system operation.

Site ST12-B - Respiration Testing Results

After the soil gas sampling was completed at Site ST12-B, an *in situ* respiration test was performed according to procedures outlined in the AFCEE bioventing protocol document (Hinchee *et al.*, 1992). Air was injected for 19.5 hours into MPA-65, MPB-71, MPB-91, and MPC-90 using 1 cfm pumps to locally oxygenate the soils. Following the air injection period, changes in soil gas oxygen, carbon dioxide, and TVH concentrations were monitored over a 96 hour period. Observed rates of oxygen utilization were then used to estimate aerobic fuel biodegradation rates. Table 4 (attached) presents the results of respiration testing performed at Site ST12-B in December 1996 and during the initial pilot test in November 1995.

Oxygen utilization rates remained high at MPB-71 and MPB-91 (0.71 and 0.25 percent oxygen consumed per hour, respectively), where the highest concentrations of petroleum hydrocarbon contamination have been observed. Petroleum hydrocarbon biodegradation rates for MPB-71 and MPB-91 were estimated at 1,400 and 590 mg of fuel per kg of soil per year, respectively, indicating that a significant amount of fuel hydrocarbons remain in soils at these locations, and that fuel biodegradation will continue to be enhanced by air injection bioventing.

At MPA-65 and MPC-90, fuel biodegradation rates of only 40 and 50 mg of fuel per kg of soil per year, respectively, were estimated, indicating that aerobic fuel biodegradation rates have decreased substantially since the initial respiration test. Laboratory soil gas TVH concentrations of 84,000 and 45,000 ppmv were detected at these points, respectively, indicating that biodegradation is occurring at very slow rates despite the presence of significant concentrations of petroleum hydrocarbons (substrate). These results indicate that bioventing is not an effective treatment method in these areas, and that an alternate form of treatment, such as soil vapor extraction (SVE) using an internal combustion engine (ICE) to treat extracted vapors would be more effective in addressing the high levels of TVH that remain in soil gas at Site ST12-B.

Analytical Results for Landfarmed Drill Cuttings

During drilling activities undertaken by Parsons ES in October and November 1995, the disposition of drill cuttings was based on physical appearance (i.e. odor and staining) and field PID soil headspace screening results. Uncontaminated soils were spread on the ground surface adjacent to each boring, and contaminated drill cuttings were placed in a lined landfarm near the front gate of the Waikakalaua FSA (Figure 1). To determine if significant levels of petroleum hydrocarbon compounds and other contaminants of concern were present in the contaminated cuttings after 1 year of landfarming treatment, a composite soil sample was collected from the landfarm on December 23, 1996. The sample was composited from three locations in the landfarm at depths ranging from 4 to 8 inches below the soil surface. The composite soil sample was sent under chain-of-custody to Inchcape Testing Services in Richardson, Texas, and analyzed for BTEX compounds by USEPA Method SW8020, polynuclear aromatic hydrocarbons (PAHs) by USEPA Method SW8310, total petroleum hydrocarbons by

USEPA Method SW8015 modified, ethylene dibromide by USEPA Method SW8260, and lead by USEPA Method SW7421. Analytical results for the composite soil sample collected from the landfarm at the Waikakalaua FSA are provided in Table 5 (attached). Lead was detected at 5 mg/kg, well below the State of Hawaii Tier 1 Action Level of 400 mg/kg (Hawaii Department of Health, 1995). There were no other analytes of concern detected in the composite soil sample.

Because there were no significant detections of contaminants in the composite soil sample, no special disposal requirements for treated soils will be needed. It is recommended that the landfarm liner be removed, and that the soils be spread uniformly over the ground surface at the FSA. Furthermore, these results demonstrate that landfarming is a suitable treatment option for drill cuttings generated during future drilling efforts at the site.

FUTURE REMEDIATION ACTIVITIES PLANNED AT HICKAM POL SITES

To complete the remediation of Sites ST12-A, ST12-B, ST10, and other petroleum-impacted sites associated with the Hickam POL system, AFCEE has contracted with The Environmental Company, Inc. (TEC) of Charlottesville, Virginia, to perform a remedial investigation/feasibility study/interim remedial action (RI/FS/IRA) at the Hickam POL system under contract number F41624-95-D-8002, Delivery Order 4. Parsons ES is under subcontract to TEC to perform the IRA portion of this project. The results of these Option 1 testing events confirm the remediation approach proposed by Parsons ES for these sites. Detailed information regarding the IRA work scope can be found in the IRA work plan (Parsons ES, 1997), found in Appendix F of the TEC work plan (1997). A summary of planned IRA activities follows.

Site ST12-A

At Site ST12-A, the vertical extent of contamination has not yet been defined, and additional VWs and MPs also are required in the silt and saprolite to obtain full-scale remediation. One deep VW and two deep MPs will be installed into basalt to the basal aquifer, if necessary, to remediate the entire vertical extent of contamination. Two shallow VWs and two shallow MPs will also be installed to define the areal extent of contamination in soils and saprolite. Following the drilling, an SVE with ICE demonstration is planned to determine the rates at which the high levels of TVH at the site can be destroyed. The SVE demonstration is scheduled for a duration of 90 days, which may be adjusted based on the results of the test. Although there are still high rates of oxygen utilization in the soils, SVE should be very cost effective at this site to rapidly remove and destroy contaminants. Following SVE treatment, bioventing treatment may be recommended to complete the remediation of residual fuel contamination in vadose zone soils and rock at this site.

Site ST12-B

At Site ST12-B, the vertical extent of vadose zone contamination has essentially been defined by the drilling and soil gas sampling activities at ST12 MW03 and MW-7

(at MW-7, static oxygen concentrations prior to system operation have not been lower than 15 percent, and TVH levels have not been higher that 540 ppmv in any soil gas sampling event). However, the areal extent of contamination has not yet been defined, and Parsons ES will install two additional VWs and two additional MPs into soils and saprolite. Following the drilling, SVE with ICE treatment has been planned to address the continuing high levels of TVH found at the site. The use of the SVE treatment is recommended at this site because of the high static oxygen levels and insignificant respiration rates that were observed in fuel-contaminated soils during the Option 1 testing event. Following SVE/ICE treatment, bioventing may be recommended to complete the remediation of vadose zone soils in the vicinity of MPB and other locations that may still display a significant oxygen demand.

Site ST10

At Site ST10, system expansion, SVE with ICE treatment, and subsequent bioventing also have been recommended. The Option 1 provided under the AFCEE Extended Bioventing contract will be used to provide 1 year of full-scale bioventing system operation and monitoring at Site ST10.

If you have any questions or require additional information, please contact me at (303) 831-8100.

Sincerely,

PARSONS ENGINEERING SCIENCE, INC.

John Ratz

John Ratz, P.E.
Project Manager

cc: Mr. William Barry, Hickam AFB
Mr. Rick McComb, Hickam AFB
Mr. Dave Dentino, AFCEE/ERD
Mr. Christopher McQuale, The Environmental Company, Inc.
Ms. Debbie Anderson, Parsons ES-Denver
Mr. John Bridenbaugh, Parsons ES-Honolulu
Mr. Rick Brettin, Parsons ES-Austin
File 727876.29110.E Letter Results Report

REFERENCES

AFCEE, 1995. Completion of One Year Bioventing Tests: Area H; Area K; and Waikakalaua Fuel Storage Annex. February 2 Memorandum.

ES, 1993. Part I Bioventing Pilot Test Work Plan and Part II Draft Interim Pilot Test Results Report for Areas H and K and Site 2, Hickam AFB, Hawaii. August.

Hawaii Department of Health, 1995. Risk-Based Corrective Action (RBCA) and Decision Making at Sites with Contaminated Soil and Groundwater. Environmental Management Division. December.

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frendt. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* Prepared for AFCEE. May.

Parsons ES, 1995. Bioventing Pilot Test and Expanded Treatability Study Work Plan, Site ST10, Hickam POL Pipeline; Sites ST12-A and ST12-B, Waikakalaua FSA; Hickam AFB, Hawaii. September.

Parsons ES, 1996. Bioventing Pilot Test and Expanded Treatability Study Results Report, Site ST10, Hickam POL Pipeline; Sites ST12-A and ST12-B, Waikakalaua FSA; Hickam AFB, Hawaii. May.

Parsons ES, 1997. Interim Remedial Action Work Plan; Sites ST12-A and ST12-B, Waikakalaua FSA; Sites ST01-A and ST01-B, Kipapa FSA; and Site ST10, Hickam POL Pipeline; Hickam POL System, Oahu, Hawaii. January.

The Environmental Company, Inc. 1997. Final Work Plan, Remedial Investigation/Feasibility Study and Treatability Study for Waikakalaua and Kipapa Fuel Storage Annexes. Hickam AFB, Hawaii. January.

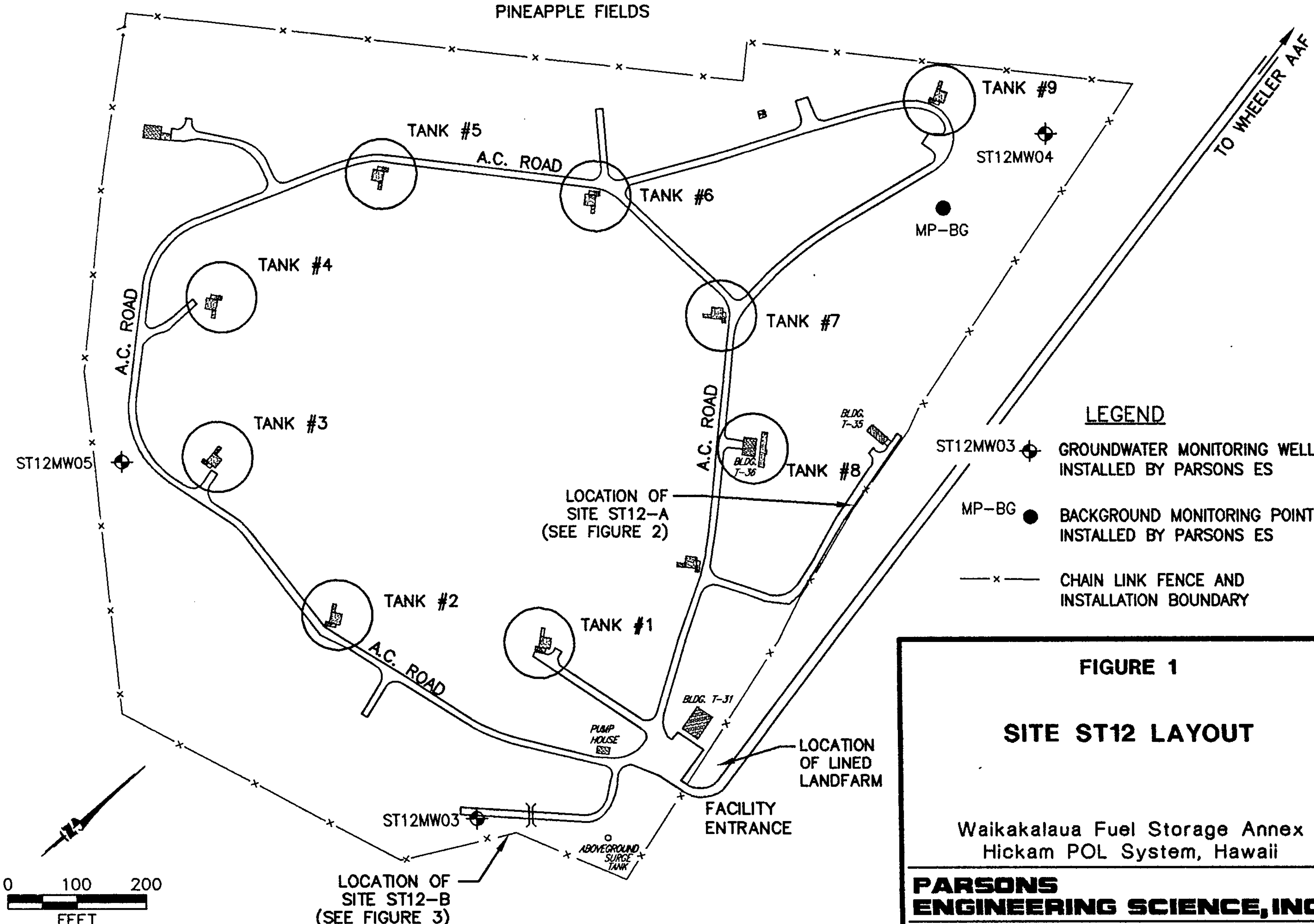

FIGURE 1

SITE ST12 LAYOUT

Waikakalaua Fuel Storage Annex
Hickam POL System, Hawaii

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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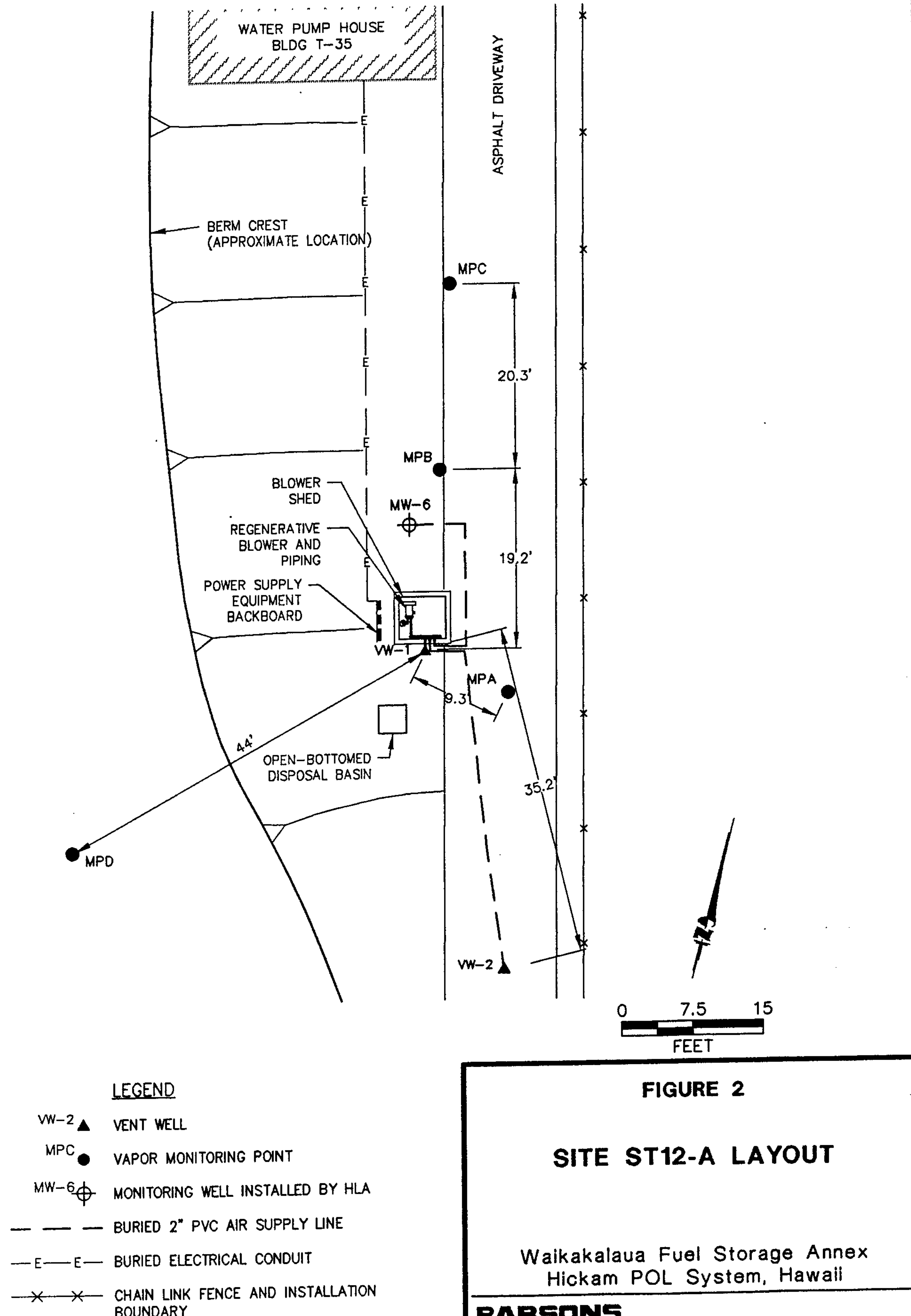

FIGURE 2

SITE ST12-A LAYOUT

Waikakalaua Fuel Storage Annex
Hickam POL System, Hawaii

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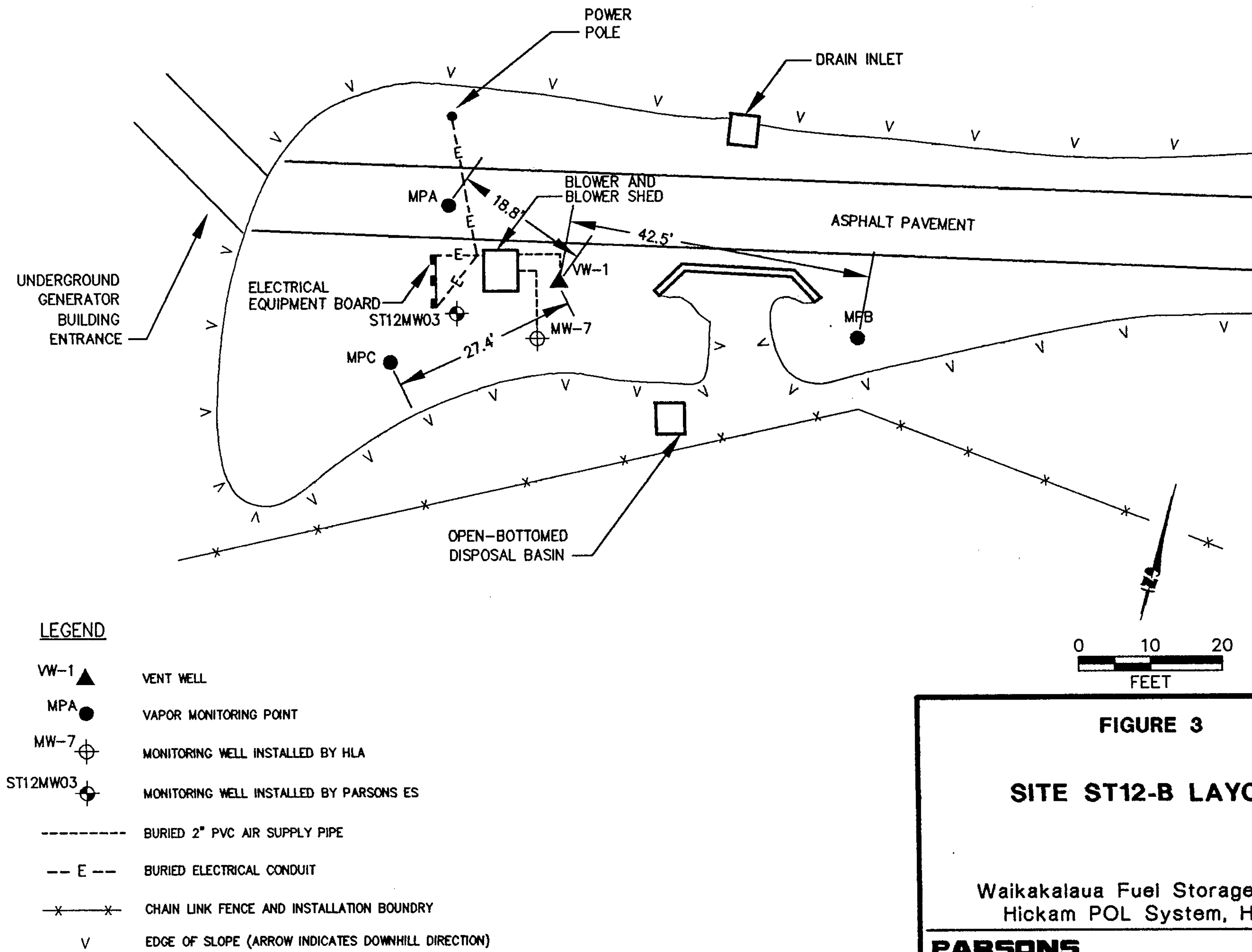

FIGURE 3

SITE ST12-B LAYOUT

Waikakalaua Fuel Storage Annex
Hickam POL System, Hawaii

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TABLE 1
SOIL GAS FIELD SCREENING AND LABORATORY ANALYTICAL RESULTS
SITE ST12-A
HICKAM AFB, HAWAII

			Field Screening Data			Laboratory Analytical Data[a]				
Sample Location	Sample Depth (feet bgs)[c]	Sampling Event[d]	Oxygen (percent)	Carbon Dioxide (percent)	TVH[b] (ppmv)[e]	TVH (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethylbenzene (ppmv)	Xylenes (ppmv)
VW-1	16-46	Initial	4.9	11.3	>20,000 [f]	19,000	46	86	16	52
	&	1-Year	13.5	2.5	150	1.9	<0.005 [g]	<0.005	<0.005	0.017
	66-101	2.5-Year	8.7	3.0	2,600	---- [h]	----	----	----	----
		3.5-Year	0.9	10.1	1,500	----	----	----	----	----
VW-2	32-107	2.5-Year	2.4	8.5	5,500	7,900	22	160	35	130
		3.5-Year	7.0	7.5	320	----	----	----	----	----
MW-6	135-150	Initial	2.9	10.8	>20,000	----	----	----	----	----
		1-Year	2.0	13.5	2,100	----	----	----	----	----
		2.5-Year	0.0	13.2	>20,000	34,000 [i]	56 [i]	260 [i]	78 [i]	330 [i]
		3.5-Year	8.1	6.0	85	100	<0.064	0.14	0.16	1.0
MPA	12.4	Initial	----	----	----	----	----	----	----	----
		1-Year	10.3	2.3	120	----	----	----	----	----
		2.5-Year	18.7	1.3	260	----	----	----	----	----
		3.5-Year	0.5	16.1	4,000	----	----	----	----	----
MPA	24.3	Initial	0.0	6.1	>20,000	22,000	<1.1	<1.1	21	66
		1-Year	0.5	8.5	940	16,000	<0.26	<0.26	17	44
		2.5-Year	13.4	3.3	1,600	----	----	----	----	----
		3.5-Year	0.0	19.1	10,000	----	----	----	----	----
MPA	70	Initial	----	----	----	----	----	----	----	----
		1-Year	----	----	----	----	----	----	----	----
		2.5-Year	----	----	----	----	----	----	----	----
		3.5-Year	0.2	>25	1,000	110,000	250	900	130	540
MPB	36.1	Initial	3.7	0.4	6,500	----	----	----	----	----
		1-Year	1.0	7.9	1,050	----	----	----	----	----
		2.5-Year	4.0	4.5	14,400	64,000	71	360	230	960
		3.5-Year	0.0	20.0	19,500	45,000	48	40	46	170
MPC	37.6	Initial	6.9	3.8	180	250	0.083	0.45	0.18	0.58
		1-Year	14.8	4.2	750	3,200	<0.11	<0.11	5.3	11
		2.5-Year	0.0	13.8	13,600	37,000	140	440	64	230
		3.5-Year	0.1	>25.0	12,400	40,500 [i]	16 [i]	2.7 [i]	6.3 [i]	16 [i]
MPC	73.2	Initial	----	----	----	----	----	----	----	----
		1-Year	14.3	5.0	8,600	----	----	----	----	----
		2.5-Year	4.5	9.5	10,800	----	----	----	----	----
		3.5-Year	0.0	19.0	16,400	----	----	----	----	----
MPD	31	2.5-Year	17.5	1.9	400	----	----	----	----	----
		3.5-Year	7.5	6.0	340	----	----	----	----	----
MPD	67	2.5-Year	5.3	6.5	5,800	----	----	----	----	----
		3.5-Year	3.0	10.0	1,000	----	----	----	----	----
MPD	101.5	2.5-Year	0.8	12.3	>20,000	39,500 [i]	97 [i]	190 [i]	63 [i]	210 [i]
		3.5-Year	0.4	>25.0	>20,000	86,000	<4.5	<4.5	<4.5	6.9

[a] Laboratory analysis of soil gas performed using USEPA Method TO-3. Laboratory TVH referenced to jet fuel (MW=156).

[b] TVH = total volatile hydrocarbons.

[c] bgs = below ground surface.

[d] Soil gas sampling performed in April 1993, May 1994, November 1995, and December 1996.

[e] ppmv = parts per million, volume per volume.

[f] > = denotes field measurement greater than maximum meter reading.

[g] < = compound analyzed for , but not detected. Number shown represents the sample quantitation limit.

[h] ---- = not analyzed.

[i] Average of primary and duplicate samples.

TABLE 2
RESPIRATION AND FUEL BIODEGRADATION RATES
SITE ST12-A
HICKAM AFB, HAWAII

Location-Depth	Initial (May 1993)			6-Month (November 1993)			1-Year (May 1994)			3.5-Year (December 1996)		
(feet below ground surface)	K_o (% O_2/hour)	Degradation Rate (mg/kg/year)[a/]	Soil Temperature (°C)	K_o (% O_2/hour)	Degradation Rate[b/] (mg/kg/year)	Soil Temperature (°C)	K_o (% O_2/hour)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)	K_o (% O_2/hour)	Degradation Rate[c/] (mg/kg/year)	Soil Temperature (°C)
VW-1	0.24	350	NM[d/]	0.022	20	NM	0.15	110	NM	NM	NC[e/]	NM
MW-6	1.08	1,130	NM	NM	NC	NM	1.20	1,600	NM	0.062	82	NM
MPA-12.4	NM	NC	22.4	NM	NC	25.4	NM	NC	26.4	NM	NC	30.2
MPA-24.3	1.02	890	NM	0.78	1,600	NM	0.66	2,300	NM	0.39	1,400	NM
MPA-70	NM	NC	26.2	NM	NC	25.1	NM	NC	25.6	NM	NC	28.7
MPB-36.1	0.06	<10	NM	NM	NC	NM	0.11	100	NM	0.47	450	NM
MPC-73.2	NM	NC	NM	0.011	<10	NM	NM	NC	NM	NM	NC	NM
MPD-101.5	NM	NC	NM	NM	NC	NM	NM	NC	NM	0.33	440	NM

[a/] Milligrams of hydrocarbons per kilogram of soil per year.
[b/] Assumes moisture content of soil is an average of the initial and 1-year measurements.
[c/] Assumes moisture content of soil at MW-6, MPA-24.3, and MPB-36.1 is equal to 1-year measurements. Moisture content at MPD-101.5 assumed to equal December 1995 measurement.
[d/] NM = not measured.
[e/] NC = not calculated.

TABLE 3
SOIL GAS FIELD SCREENING AND LABORATORY ANALYTICAL RESULTS
SITE ST12-B
HICKAM AFB, HAWAII

			Field Screening Data			Laboratory Analytical Data[a]				
Sample Location	Sample Depth (feet bgs)[c]	Sampling Event[d]	Oxygen (percent)	Carbon Dioxide (percent)	TVH[b] (ppmv)[e]	TVH (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethylbenzene (ppmv)	Xylenes (ppmv)
VW-1	28-98	Initial	1.8	13.5	>20,000 [f]	150,000	1,100 M[g]	1,500	520	1,300
		1-Year	11.5	5.5	2,800	9,500	<1.1 [h]	<1.1	<1.1	2.7
MW-7	135-155	Initial	15.0	2.9	540	---- [i]	----	----	----	----
		1-Year	----	----	----	----	----	----	----	----
MPA	25	Initial	19.6	1.7	1,600	----	----	----	----	----
		1-Year	----	----	----	----	----	----	----	----
MPA	65	Initial	17.2	4.7	6,600	----	----	----	----	----
		1-Year	16.1	6.5	>20,000	84,000	85	90	<5.4	180
MPA	87.5	Initial	6.6	10.0	>20,000	77,000	590	1,200	270	970
		1-Year	19.8	1.5	2,000	----	----	----	----	----
MPB	25	Initial	11.2	7.2	3,200	----	----	----	----	----
		1-Year	5.4	12.4	140	----	----	----	----	----
MPB	71	Initial	0.8	12.2	>20,000	100,000	180	680	510	1,300
		1-Year	0.3	23.0	>20,000	140,000	130	160	130	320
MPB	91	Initial	0.7	17.5	>20,000	140,000	1,100	820	330	830
		1-Year	0.0	>25	440	200,000	560	210	140	500
MPC	25	Initial	17.7	3.5	3,900	----	----	----	----	----
		1-Year	9.5	6.5	100	----	----	----	----	----
MPC	65	Initial	10.4	7.8	12,800	19,000	150	320	86	260
		1-Year	14.5	7.0	3,200	16,000	23	38	14	82
MPC	90	Initial	7.8	9.5	>20,000	32,000	250	500	130	430
		1-Year	12.8	4.8	9,600	45,000	50	110	25	170

[a] Laboratory analysis of soil gas performed using USEPA Method TO-3. Laboratory TVH referenced to jet fuel (MW=156).
[b] TVH = total volatile hydrocarbons.
[c] bgs = below ground surface.
[d] Soil gas sampling performed in November 1995 and December 1996.
[e] ppmv = parts per million, volume per volume.
[f] > = denotes field measurement greater than maximum meter reading.
[g] M = reported laboratory value may be biased due to apparent matrix interferences.
[h] < = compound analyzed for, but not detected. Number shown represents the sample quantitation limit.
[i] ---- = not analyzed.

TABLE 4
RESPIRATION AND FUEL BIODEGRADATION RATES
SITE ST12-B
HICKAM AFB, HAWAII

Location-Depth	Initial (November 1995)			1-Year (December 1996)		
(feet below ground surface)	K_o (% O_2/hour)	Degradation Rate (mg/kg/year)[a/]	Soil Temperature (°C)	K_o (% O_2/hour)	Degradation Rate[b/] (mg/kg/year)	Soil Temperature (°C)
VW-1	0.90	1,300	NM[c/]	NM	NC[d/]	NM
MPA-65	NM	NC	NM	0.018	40	NM
MPA-87.5	0.08	190	32.4	NM	NC	NM
MPB-71	0.63	930	NM	0.71	1,400	NM
MPB-91	0.98	2,300	NM	0.25	590	NM
MPC-90	0.15	370	NM	0.021	50	NM

[a/] Milligrams of hydrocarbons per kilogram of soil per year.
[b/] Assumes soil moisture content is equal to November 1995 values.
[c/] NM = not measured.
[d/] NC = not calculated.

TABLE 5
LANDFARM SOIL SAMPLE RESULTS
SITE ST12
HICKAM AFB, HAWAII

Analyte[a/]	Tier 1 Action Level[b/] (mg/kg)	Soil Sample Concentrations (mg/kg)[c/]
Benzene	0.05	<0.001[d/]
Toluene	16	<0.002
Ethylbenzene	0.50	<0.002
Xylenes	23	<0.002
Benzo(a)pyrene	1.0[e/]	<0.0308
Acenaphthene	18[f/]	<0.242
Fluoranthene	11[f/]	<0.0282
Naphthalene	41[f/]	<0.402
Lead	400[e/]	5
TPH[h/]-residual fuels	5,000	<20
TPH-middle distillates	5,000	<20
TPH-volatile gasolines	2,000	<0.05

[a/] Analytical methods: BTEX by USEPA Method SW8020, polynuclear aromatic hydrocarbons by USEPA Method SW8310, total petroleum hydrocarbons (extractable) by USEPA Method SW8015M, total petroleum hydrocarbons (volatile) by USEPA Method SW6030/8015M.

[b/] Hawaii Department of Health Tier 1 Action Level: rainfall ≤ 200 cm/year (1995).

[c/] Milligrams of contaminant per kilogram of soil.

[d/] < = denotes sample concentration is less than sample quantitation limit shown.

[e/] Direct-exposure concerns dominate. For unmarked criteria, groundwater-protection concerns dominate.

[f/] Saturation concentration, groundwater-protection concerns dominate.

[h/] TPH = total petroleum hydrocarbons.